Appendix B. Annual report – Invasive species early detection monitoring (pilot study) 2007.

National Park Service
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Annual Report – Invasive Species Early Detection Monitoring (Pilot Study) 2007

Natural Resource Technical Report NPS/KLMN/NRTR—2008/105

ON THE COVER
Pampas grass (*Cortaderia jubata*), a highly invasive species at Redwood.
Photograph by: NPS staff

Annual Report – Invasive Species Early Detection Monitoring (Pilot Study) 2007

Natural Resource Technical Report NPS/KLMN/NRTR—2008/105

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Contents

Tables

Figures

Abstract

The Klamath Network completed a pilot study to test the Invasive Species Early Detection Protocol at Redwood National and State Parks in the fall of 2007. The methods and results are described herein, along with lessons learned. This report also serves as a template for future annual reports on invasive species monitoring. In general, the pilot study confirmed that the approach would be feasible, with some unsubstantial modifications. The data collected, however, are not likely to be sufficient in and of themselves for modeling individual invasive species habitat relationships. However, the data may be supplemented with data from the vegetation protocol or data collected by parks.

Introduction

In the fall of 2007, the Klamath Network (the Network) undertook a pilot study to test our proposed invasive species early detection monitoring protocol. The pilot study was completed at Redwood National and State Parks (hereafter Redwood). Results of the pilot study are described here, in the annual report format the Network proposes to employ in future monitoring years. These annual reports are intended to quickly summarize the work completed in a given field season. They are targeted towards assisting park managers with the parks' rapid response efforts. A management goal identified in the Klamath Network's Invasive Species Early Detection Protocol is the "Early detection of invasive species to assist managers in controlling or preventing new populations of high priority invasives from establishing." To accomplish this goal, it is important that the format and content of the report be optimized for usefulness to managers. This version of the report will be revised and refined based on feedback from park managers. Thus, although the results presented here are specific to Redwood, the report format will be of interest across the Network to help improve the link between future monitoring and management.

Methods

A. Pre-field Preparation

Site Selection

Three km road and trail segments were selected subjectively from all around Redwood. Roads and trails that are to be decommissioned were excluded. The 28 segments were divided almost equally between remaining roads and trails. Segments were selected to represent the full range of environments and circumstances that may be encountered within the park (Figure 1). They range from heavily used roads and trails with easy access to those that are remote and lightly used. However, no highways were picked and all but one trail segment started at a trailhead. Thus, very busy roads (which have high levels of infestation by invasives) and very remote trail areas, far from trailheads (which exist in the park but are not extensive) are not represented. Remote trails are expected to be the least invaded but are perhaps the most important areas to eliminate incipient infestations. Future monitoring will not avoid these trail areas; however, for safety reasons, they will avoid busy highways. Maps of infestations below show the segments that were selected and monitored. In the future, segments will be probabilistically selected.

Figure 1. Roads and trails selected for monitoring in the pilot study at Redwood. Only selected segments of these roads and trails were monitored.

Species Selection

The species for monitoring were selected through an analytical hierarchy process developed by Robert Klinger and Matthew Brooks of the USGS, based on a rank using a system developed by Randall et al. (2001). The detailed process for each park is described in the protocol (Odion et al. in review). At Redwood, expert opinion of park managers, particularly that of Stassia Samuels, was a key component in the ranking. Of the 275 non-native plant species considered for ranking at Redwood, 226 were determined not to pose serious threats or be in need of monitoring. Thirteen were then classified as being in the colonizing phase, 22 in the establishment phase, and 19 in the spread/equilibrium phase (see protocol, Odion et al. in review, for details). Species in the equilibrium/spread phase were not considered for early detection because they are already widespread. The species in each phase were then ranked based on a system consisting of 20 criteria. Relatively low ranking species were excluded from the prioritized species list; the rest of the species were selected (Table 1).

Table 1. Prioritized invasive species list for Redwood.

Scientific Name	Common Name
Acacia dealbata	Mimosa
Carpobrotus chilensis	Sea Fig
Centaurea maculosa	Spotted Knapweed
Centaurea solstitialis	Yellow Starthistle
Cortaderia spp.	Pampas Grass
Crataegus monogyna	Oneseed Hawthorn
Delairea odorata	Cape Ivy
Erica lusitanica	Spanish Heath
Foeniculum vulgare	Fennel
Hypericum perforatum	St. Johnswort
Linaria genistifolia	Broomleaf Toadflax
Lupinus arboreus	Yellow Bush Lupine
Polygonum cuspidatum	Japanese Knotweed
Polygonum sachalinense	Giant Knotweed
Prunus avium	Sweet Cherry
Robinia pseudoacacia	Black Locust
Rubus laciniatus	Cut Leaved Blackberry
Ulex europaeus	Gorse
Verbascum thapsus	Common Mullein

Electronic Devices

A TrimbleGeoXT and a Garmin V GPS unit were both used in the field. GIS data and the database for recording information were loaded onto the Trimble unit prior to field sampling. GIS data included aerial photography and Digital Raster Grid topographic base maps to aid with navigation. The database was developed from The Nature Conservancy's Microsoft Access-based Weed Information Management System (WIMS) by Sean Mohren and included pick lists and other efficiency-maximizing features for recording data on the Trimble unit. The Garmin unit served as a backup for collecting geographic coordinates of infestations and for navigation.

B. Field Sampling

Site Sampling
Monitoring of prioritized species occurred along 12 roads and 16 trail segments within Redwood. Sampling took place from September 12 to October 18, 2007. Segments were 3 km long, except where the total trail or road length was shorter than this. Segments were divided into 500 m subsegments (Figure 2). Starting with the most accessible subsegment of a road or trail, the field crew traversed the full segment. A GPS record of the location was created and the estimated infestation size of prioritized species visible from the route was recorded. Detection distance was not consistent between segments. Visibility was reduced in areas with more dense vegetation and was greater in open habitats. Recording these changes in detection distance was not considered feasible. Infestations were considered distinct if separated by the maximum detection distance or 20 m. If non-native populations could be eradicated within 2 minutes by hand, the crew eradicated them and this effort was recorded in the database.

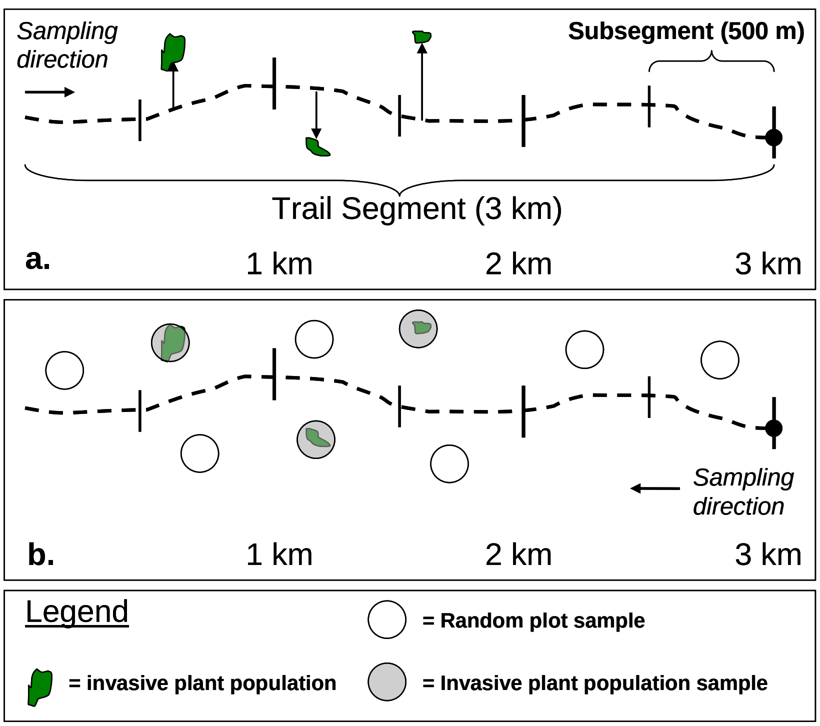


Figure 2 a and b. Illustration of the invasive species early detection sample design tested along road and trail segments in Redwood: a.) location mapping and sampling of invasive plant populations; b.) plot sampling of random locations and the invasive plant populations located.

On roads and trails, sampling proceeded until the end of the segment. Six random plots along the segment were also sampled to document conditions in uninfested areas, to aid with future invasive species habitat modeling. The crew placed one 100 m^2 plot randomly in each subsegment (Figure 2). A random side of the road or trail was selected for sampling, then a random number between 6 and 494 was chosen for the longitudinal coordinate and a random number between 6 and 14 was chosen for the transverse coordinate (distance from road or trail edge) of the plot center. All random plot locations were determined prior to arrival in the field. Discrepency between the locations of roads and trails in GIS space vs. the field meant that plots were not the same distances from roads and trails as determined in GIS. A Garmin GPS unit, in combination with a TrimbleGeoXT, was used to navigate to segments and plots in the field.

Additional circular 100 m^2 plots were centered on infestations. The number of the infested plots sampled depended on the number of infestations encountered en route to the end point. The maximum number of plots for each invasive species was three. There are a number of different scenarios for locating these plots:

1. For each invasive in which there were three or fewer infestations on a segment, a plot was centered on each infestation, regardless of the infestation's location.
2. For each invasive for which there were more than three infestations, a total of three were chosen to sample. Sampling sites were chosen to maintain their dispersion by randomly selecting sites from three different subsections containing infestations. If infestations were only found in two subsections, all three sampling locations would be selected at random from these.
4. If more than three infestations of an invasive occurred and they were all located in one subsegment, sampling plot locations were chosen at random.

To choose infestations randomly, infestations were numbered. A random number from the appropriate range, depending on the considerations described above, was chosen using the seconds' value attained by periodically looking at a digital watch.

The circular 100 m plots (random or infestation) were laid out by measuring or pacing off the 11.34 m diameter in two perpendicular lines. After pacing was calibrated, it was used in lieu of measuring tapes, which were difficult to use in dense vegetation.

Sites Sampled
Segments were selected from the roads and trails that are listed in Table 2. Names are from the Redwood GIS database.

Table 2. List of the 28 randomly or haphazardly selected roads and trails from which segments analyzed in this study were selected.

Roads	Trails
Alder Camp	Boy Scout Tree
Bald Hills	Coastal Trail/South
Cal-Barrel	Coastal Trail/Lagoon Creek
C-Line East	Dolason
Coastal Drive	Flint Ridge
Davison	James Irvine
Enderts Beach	LadyBird Johnson
Geneva	Little Bald Hills
Gold Beach	Lostman Creek
Hilton Road West	Mill Creek Horse Trail
Howland Hills	Rellim Ridge
Klamath Beach	Redwood Creek
	Rhododendron
	Skunk Cabbage
	Trillium Falls
	West Ridge

Plot Measurements Taken

Infestation Size: If the plot was centered on an infestation, the invasive cluster size was classified as being less than 1 m, 1-25 m, or greater than 25 m.

Slope: A LaserTech TruePulse was used to record percent slope of the ground surface in the sample plot, facing down slope.

Aspect: The aspect was recorded in compass degrees.

Coverage: Supposing a view above the plant, foliar cover was recorded as the area of ground obscured by the leaf surface area of the plant. The percent plot cover of evergreen and deciduous trees; herbs and shrubs; as well as litter, woody debris, and bare ground were all estimated. All percentages were ocular estimates.

Soil Disturbance: Ocular estimates of soil disturbance were recorded as a percentage of the plot area. If the disturbance was natural (e.g., a fallen tree) or was not recent, a note was made.

Light Index: This was measured using a densiometer total count of shaded points.

Phenology: Either the phenology of the community or the invasive, depending on whether the plot was covering an infestation or if it was a random sample plot. Phenology was described as one of the following: bolting, bud, dead, flowering, mature, rosette, seed set, or seedling.

Topography: This is the general landform of the survey site. Plot topography was described with one of the following terms:

- Level if the plot was level in all directions.
- Toe slope if the plot was at the bottom of a hillslope adjoining a valley bottom, usually with a shallower slope than the adjacent hillslope.
- Lower slope if the plot was on the lower 1/3 of a hillslope.
- Mid slope if the plot was on the middle 1/3 of a hillslope.
- Upper slope if the plot was on the upper 1/3 of a hillslope.
- Escarpment if the plot was on a vertical area of exposed rock or soil.
- Ledge if the plot was on a flat area adjacent to a drop-off.
- Crest if the plot was on an apex, hill, or ridge.
- Depression if the plot was at the base of a depressed area, concave in both directions.
- Draw if the plot was in an area that is concave across the slope but straight down the slope.

Hydrology:* Plots were classified as one of the following three types; flooded, seep, or upland.

- Flooded indicates the land surface was covered with water throughout the year in all years and the vegetation was composed of obligate hydrophytes.
- Seep indicates a site of low volume groundwater discharge.
- Upland plots indicate a site that only contain surface water during periods of heavy precipitation.

**A seasonally flooded category will be added in the future.*

Land use: It was recorded if the plot sites had been altered for one of the following uses: cultivation, campground, ditch/diversion, graded, pasture, logging, mining, homestead, or roads.

Species composition: A list of vascular plant species found within the plot was also compiled while surveying the area for the above mentioned parameters.

C. Data Entry

The field crew used a TrimbleGeoXT as an electronic data recorder to note the location and size of infestations encountered along segments. All of the parameters described above were entered into this unit for each plot, as well as the geographic coordinates of the plot's location. Each entry was assigned an ID which included the park code, date, time, and whether the plot was random or an infestation. This ID corresponds to the same entry recorded on paper datasheets, which were used in the field to back up the electronic system. To expedite sampling, the list of species found in each plot was recorded only on the datasheets.

All data collection from October 4 to October 18, 2007, was completed without the use of the Trimble unit. For these segments, all analyses were recorded on paper datasheets and locations were recorded using the latitude/longitude coordinates taken from the Garmin GPS unit. Upon arrival in Ashland, these data were manually entered onto a spreadsheet.

D. Data Analysis

Correlations among the plot variables were calculated for both *Hypericum perforatum* and *Cortaderia selloana*, the two most common species. A Spearman rank order correlation coefficient was calculated because cover data for these species were categorical.

Spatial Modeling

General linear modeling was used to produce interpolated maps from point sampling data of the mean response variables and associated standard error terms. These analyses used the following landscape scale variables generated in ArcGIS 9 to create species-environment matrices for each the species being modeled:

1. Kernel Density of Paved Roads within 2,000 m of Point.
2. Kernel Density of Trails within 2,000 m of Point.
3. Kernel Density of Unpaved Roads within 2,000 m of Point.
4. Euclidean Distance to Trails.
5. Euclidean Distance to Unpaved Roads.
6. Euclidean Distance to Paved Roads.
7. Euclidean Distance to Coastline.
8. Euclidean Distance to Perennial and Intermittent Streams.
9. Euclidean Distance to Perennial Streams.
10. Growing Degree Days Base 50 in Fahrenheit.
11. Conifer Cover from Above (Calveg Vegetation Data).
12. hdw_cfa – Hardwood Cover from Above (Calveg Vegetation Data).
13. tot_cfa – Total Cover from Above (Calveg Vegetation Data).
14. cti – Compound Topography Index (CTI) or the Steady State Wetness Index.
15. ntpi – Normalized Topographic Position Index.
16. aspect – Aspect.
17. slp_d – Slope in Degrees.
18. elev – Elevation in Meters.
19. ill - Illumination Index.
20. cv_usgs – USGS Anderson Major Cover Classes (Calveg Vegetation Data).
21. cv_type – Cover Type from (Calveg Vegetation Data).
22. awc – Available Water Holding Capacity, Water Available to Plants.
23. bdepth – Distance from Top of the Soil to the Base of the Soil Horizon.
24. ph – Relative Acidity or Alkalinity of the Soil.

These matrices were imported in the statistical package R, where species-environment relationships were explored and modeled. Correlations among all variables were considered and different model permutations run with a subset of variables producing the most parsimonious models, as determined using a testing dataset for model validation. These models were mapped using ArcGIS. Detailed methods and the step-by-step instructions were produced in a report: Step by Step Invasive Alien Plant Predictive Mapping Methods for the Klamath Network, NPS, by GIS specialist Andrew Duff. Model outputs are shown below.

E. Results

Approximately 3 to 6 hours were required for segments to be completely traversed with all infestations recorded and plots sampled. This time frame does not include travel to or from the start point of each segment. Analyzing each plot and compiling a species list required about 10-20 minutes, not including travel time. Travel time varied greatly depending on the location of the starting point of each segment. The field crew was stationed in Requa and therefore started from this point each day.

Of the 19 prioritized invasive species, only seven were found on the 28 segments surveyed for this project (Table 3). *Cortaderia selloana* and *Hypericum perforatum* were the only species found with some regularity. Several of the target species not listed here were identified in areas within the park but were not surveyed because they were not visible from the selected segments. This list includes *Acacia dealbata, Polygonum sachalinense,* and *Verbascum thapsus.* These were seen in the Hiouchi Flats area. Other target invasives were seen on lands neighboring the park but also were not surveyed. These include *Polygonum sachalinense* and *Polygonum cuspidatum*. *Polygonum* species were seen in ditches bordering Hwy 101 between Requa and Lagoon Creek. *Polygonum sachalinense* was also established on Klamath Overlook Road.

Table 3. List of prioritized invasive species encountered in Redwood, the segment(s) they were found on, and the number of occurrences per segment.

Species	*Segment*	*Number of Infestations*
Centaurea maculosa	Coastal Trail/Lagoon Creek	1
Cortaderia selloana	C-Line East	3
Cortaderia selloana	Coastal Trail/Lagoon Creek	8
Cortaderia selloana	Coastal Trail South	17
Cortaderia selloana	Geneva Road	4
Cortaderia selloana	Gold Bluffs Beach Road	8
Cortaderia selloana	Hilton Road/West	2
Cortaderia selloana	Trillium Falls	2
Crataegus monogyna	Enderts Beach Road	1
Foeniculum.vulgare	Coastal Trail/Lagoon Creek	2
Foeniculum vulgare	Klamath Beach Road	1

Table 3. List of prioritized invasive species encountered in Redwood, the segment(s) they were found on, and the number of occurrences per segment (continued).

Species	*Segment*	*Number of Infestations*
Hypericum perforatum	Bald Hills Road	14
Hypericum perforatum	C-Line East	23
Hypericum perforatum	Cal-Barrel Road	2
Hypericum perforatum	Coastal Drive	1
Hypericum perforatum	Dolason Trail	2
Hypericum perforatum	Enderts Beach Road	1
Hypericum perforatum	Flint Ridge Trail	2
Hypericum perforatum	Geneva Road	4
Hypericum perforatum	Lost Man Creek	1
Hypericum perforatum	Trillium Falls	1
Prunus avium	Skunk Cabbage Trail	1
Rubus laciniatus	Bald Hills Road	1
Rubus laciniatus	Cal-Barrel Road	3

Three of the roads and trails, C-line east Bald Hills Road and Coastal Trail, accounted for most of the infestations (Table 4). Infestations in other locations were rare.

Table 4. Infestations by road and trail.

Trail	Infestations	*Hypericum perforatum*	*Cortaderia jubata*	**Other species**
Alder Camp	0	0	0	0
Bald Hills Road	15	14	0	*Rubus laciniatus* (1)
Boy Scout Tree Trail	0	0	0	*0*
Cal Barrel Road	5	2	0	*Rubus laciniatus (3)*
C-Line East	24	23	2	*0*
Coastal Drive	1	1	0	0
Coastal Trail (South)	16	0	16	0
Coastal Trail Lagoon Creek	11	0	8	*Foeniculum vulgare* (2); *Centaurea maculosa* (1)
Davison Road	0	0	0	0
Dolason Trail	1	1	0	0
Enderts Road	2	1	0	*Crataegus monogyna* (1)
Flint Ridge Trail	2	2	0	*0*
Geneva Road	5	4	3	0
Gold Bluffs Beach Trail	8	0	8	0
Hilton Road (west)	2	0	2	0
Howland Hill Road	0	0	0	0
James Irvine Trail	0	0	0	0
Klamath Beach Trail	1	0	0	*Foeniculum vulgare* (1)
Lady Bird Johnson	0	0	0	*0*

Table 4. Infestations by road and trail (continued).

Trail	Infestations	*Hypericum perforatum*	*Cortaderia jubata*	**Other species**
Little Bald Hills Trail	0	0	0	*0*
Lost Man Creek Trail	1	1	0	*0*
Mill Creek Horse Trail	0	0	0	*0*
Redwood Creek Trail	0	0	0	0
Rellium Ridge Trail	0	0	0	0
Rhododendron Trail	0	0	0	0
Skunk Cabbage Trail	1	0	0	*Prunus avium* (1)
Trillium Falls Trail	2	1	1	0
West Ridge Trail	0	0	0	0

A full list of infestation locations that can be imported into GPS is provided with this report.

Correlations among the cover of *Hypericum* and *Cortaderia* and the plot variables are shown in Tables 5 and 6. *Hypericum* showed fairly strong negative correlations with woody debris, light, and especially litter. *Cortaderia* showed similarly strong negative correlations with these variables and an equally strong positive correlation with bare ground.

Predictive modeling outputs are shown below for *Hypericum* (Figure 3a) and *Cortaderia* (Figure 3b). For *Hypericum*, variables included in the model were: unpaved road density, trail density, and aspect. For *Cortaderia*, distance to coast, aspect, and slope were the variables included. Overall, the results demonstrate that the sample design can provide useful data for predictive modeling. Models will improve considerably with more spatial data and the addition of data from the vegetation monitoring protocol. In addition, the cover of invasives will be measured continuously, so there will be more than three cover classes for regressing the dependent variable.

Table 5. Correlation matrix for *Hypericum perforatum* and plot variables.

	Hypericum cover	Slope	Aspect	Ever-green cover	Decid-uous cover	Herb-aceous cover	Shrub cover	Woody debris	Litter	Bare ground	Light Index	Disturbance
Hypericum cover	1.000											
Slope	-0.171	1.000										
Aspect	-0.042	0.218	1.000									
Evergreen cover	-0.251	0.169	0.075	1.000								
Deciduous cover	-0.074	0.036	0.051	-0.251	1.000							
Herb cover	0.106	0.119	0.074	-0.031	-0.275	1.000						
Shrub cover	-0.111	-0.051	-0.134	-0.095	0.258	-0.387	1.000					
Woody debris	-0.389	0.265	-0.009	0.527	-0.015	-0.030	0.138	1.000				
Litter	-0.459	0.201	0.044	0.610	0.079	-0.069	0.185	0.590	1.000			
Bare ground	0.215	-0.072	-0.053	-0.427	-0.018	-0.018	-0.250	-0.403	-0.796	1.000		
Light index	-0.363	0.200	-0.028	0.538	0.196	-0.278	0.333	0.511	0.589	-0.417	1.000	
Disturbance	0.242	-0.027	0.082	-0.363	0.133	0.067	-0.178	-0.346	-0.477	0.587	-0.378	1.000

Table 6. Correlation matrix for *Cortaderia jubata* and plot variables.

	Cortaderia cover	Slope	Aspect	Ever-green cover	Decid-uous cover	Herb-aceous cover	Shrub cover	Woody debris	Litter	Bare ground	Light index	Disturbance
Cortaderia cover	1.000											
Slope	0.162	1.000										
Aspect	0.124	0.211	1.000									
Evergreen cover	-0.339	0.073	0.006	1.000								
Deciduous cover	0.042	0.009	0.047	-0.282	1.000							
Herbaceous cover	0.049	0.131	0.112	0.007	-0.203	1.000						
Shrub cover	-0.127	-0.144	-0.182	-0.064	0.250	-0.388	1.000					
Woody debris	-0.426	0.108	-0.097	0.561	-0.055	0.022	0.145	1.000				
Litter	-0.498	0.022	-0.061	0.641	0.060	0.002	0.167	0.606	1.000			
Bare ground	0.404	0.047	0.050	-0.501	-0.052	-0.085	-0.170	-0.482	-0.861	1.000		
Light index	-0.343	0.090	-0.115	0.561	0.176	-0.205	0.319	0.520	0.610	-0.493	1.000	
Disturbance	.190	-0.014	0.119	-0.355	0.221	0.059	-0.057	-0.290	-0.377	0.453	-0.322	1.000

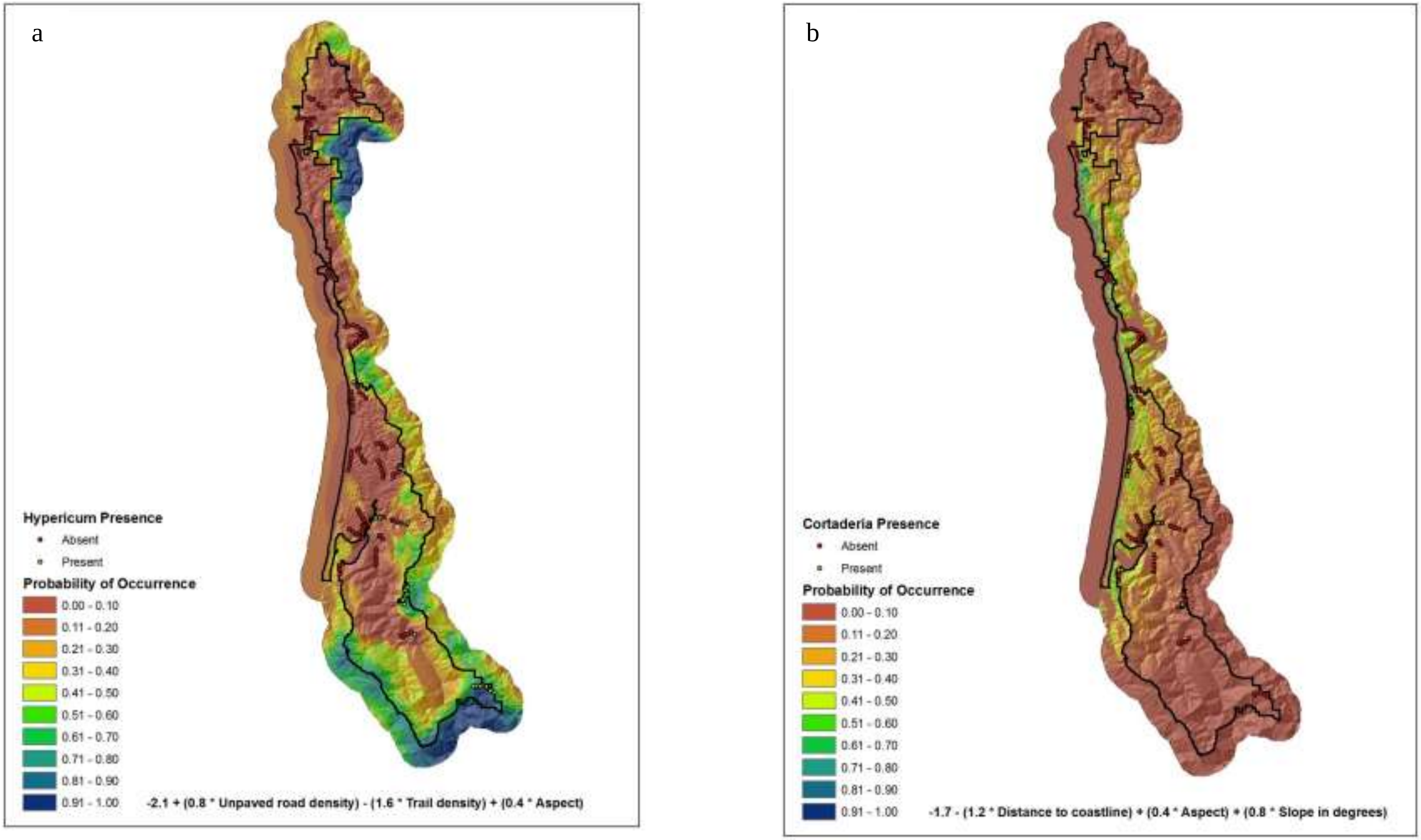


Figure 3. Interpolated surface showing the probability of occurrence of a.) Klamath weed (*Hypericum perforatum*) at Redwood National Park.

Discussion and Management Implications

The following discussion focuses on lessons learned in the context of improving the protocol.

A. Species Prioritization

Dr. Solomeshch, who lead the pilot study, concluded that the prioritization was quite sound and accurate. However, he did suggest that three species were misclassified.

Hypericum perforatum was classified into colonization phase, defined as "present in region but not site." During the pilot study, 51 infestations of *Hypericum perforatum* were documented, more than any other species. At the same time, *Delairea odorata, Linaria dalmatica,* and *Geranium robertianum*, which were classified into establishment phase, were not found. Other species such as *Centaurea maculosa* and *Rubus laciniatus*, which were also classified into establishment phase, were found one and four times, respectively.

Cirsium arvense was classified into spread/equilibrium phase of the invasion process. Distribution of this species was rather localized within Redwood. Two big patches (more than 500 m^2) were observed during the pilot study. There are many more sites where it can potentially become established; it can invade new locations quickly because it spreads by wind. However, this species is certainly not yet in the equilibrium phase of invasion. It fits better into the establishment phase.

Cytisus scoparius was classified into spread/equilibrium phase of the invasion process. Though locally abundant, this species still occurs only in select areas. It does not cover all appropriate habitats and has the potential for spreading widely. It appears to fit better into the establishment phase of invasion.

A related concern that applies to *Cytisus scoparius* was noted by Stassia Samuels, Redwood National Park Plant Ecologist, in implementing the pilot study. The concern is that there are some species that may be classified in the equilibrium phase (thus, not monitored) that would best be regarded as colonizers in remote parts of the park. *Hedera helix* is another good example. *Hedera*, *Cytisus,* and some other species are well established along the coast or along transportation corridors but not in the old- growth redwood and mixed evergreen forests in more remote areas of the park. It would be most unfortunate ecologically and for the preservation of unimpaired conditions for future generations if new infestations of such pernicious exotics colonized remote areas with high ecological integrity. This illustrates the difficultly of applying the prioritization across heterogeneous landscapes and is especially a concern at a big park like Redwood.

To consider the ecological integrity of different areas, the rankings could be placed on an x-axis and the y axis could represent relative ecological integrity (Figure 4). At the highest levels of integrity, any invader should probably be monitored. Where ecological integrity is very low, it may not make sense to monitor invasives. These factors were considered in the final prioritization of invasives developed for the draft protocol (Odion et al. in review).

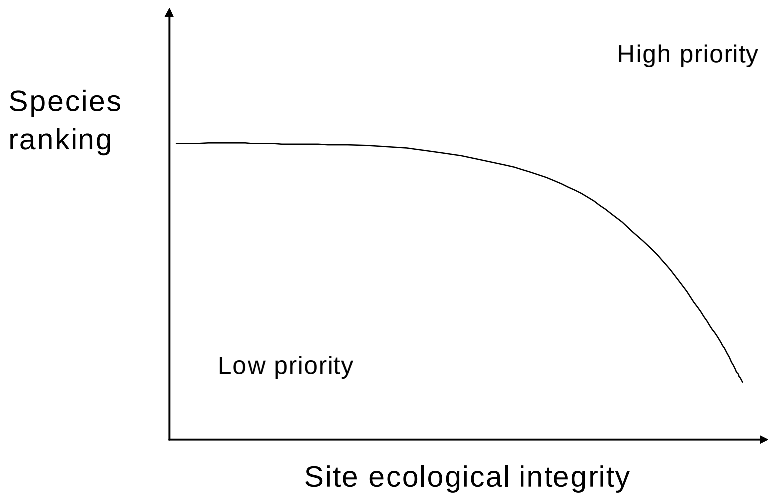


Figure 4. Conceptual model of how invasive species priorities may change as a function of the ecological integrity of sites where they are found.

Another item that came up in the pilot study was a species that turned out to be a much bigger concern than expected: holly (*Ilex aquifolium*). The reason it is a big threat is related to Figure 4. It has the capacity to invade habitat with high ecological integrity (and public interest), intact old-growth redwood forest. Holly has begun invading in areas that are not too distant from Crescent City, where it is commonly planted. Presumably, with its bright red berries, it is dispersed by birds such as Robins and Waxwings. The discovery of a greater than anticipated problem with holly brings up the issue of what to do when the rankings do not identify something as a highly significant threat when it turns out to be, at least in some areas. Because the pilot study found that the rankings need to be modified, the protocol calls for updating the rankings for all parks after the first sampling season.

B. Implications of Data Collected

The data collected during the pilot study may not suffice for predictive modeling of most invasive species. While this may in part reflect a relatively short sampling period for a park like Redwood, the real field season will likely only be slightly longer. By monitoring only species in the colonization and establishment phases, species abundant enough to provide sufficient sample sizes for monitoring will be avoided. Thus, modeling for most species may require or be improved through use of data collected under the vegetation protocol or other invasive species data at the parks. In this regard, it is important to note that the invasive species and vegetation protocol draft designs have been made as compatible as possible through the use of 100 m^2 plot sizes. Modeling may also become more possible after several sampling seasons in a park. There may additionally be some predictive relationships detectable using data from multiple parks or for multiple species. For example, such data might be useful to determine the effects of proximity to trailhead, how heavily roads and trails are used, etc. on invasive species occurrences. At this time, we do not consider it justifiable to change the early detection protocol to include monitoring of well established species in the equilibrium phase in order to increase the sample size of detections. Reasons for focusing on early detection are explained in the protocol narrative and the NPS/USGS Invasive Species Early Detection Handbook.

Variations in the Time Required for Sampling

Variations in the time required to finish different segments depended mainly on the number of infestations, ease of obtaining satellite signals with the GPS, and the level of difficulty associated with the hike.

Locating the pre-determined random plots was particularly difficult in dense forest stands where obtaining an accurate GPS signal required the crew to find an opening in the canopy and sometimes wait for a signal.

Ways to Speed Up Sampling

When segments were not on trails but on lightly used roads (typically unpaved roads), we found that moving the vehicle along the road while navigating the segment saved the field crew 45 minutes to one hour. Instead of having to hike the 3 km back to the starting point, it was then possible to drive that distance. Using this method, one surveyor was hiking all segments, while the second surveyor drove the vehicle, parked it near the next random point and hiked back toward the first surveyor, watching the roadsides for target species. This method was especially beneficial when it was raining. However, we do not recommend it on relatively busy roads for safety reasons.

Surprisingly, recording the plot data on paper (October 4 and 18) speeded up the process because the second surveyor measured light index, slope, and aspect. Previously, the first surveyor did all measurements and estimates while the second one only had time to enter data into the Trimble unit. Upon arrival in Ashland, these data were manually entered in the Trimble unit. As a result, during the last four days we sampled 25 percent of all trails even though that the weather became more difficult.

Sometimes it was extremely difficult and time consuming to place measuring tapes on the ground. Examples include plots with a high density of thorny shrubs, plots on steep slopes (>30 degrees), and plots in second growth forests with big logs (1-2 m diameter) laying on the ground and covered with shrubs and litter. We found that in most cases, we were able to collect required information without placing measuring tapes on the ground. Our guess is that this might save at least 5-10 minutes for each assessment, without any effect on the data quality.

Solving Technical Problems

Changing random plot location: If a random plot was located in the middle of the road and did not have plant cover at all, we shifted the location of the plot on the roadside. Sampling the middle of the road would certainly be faster because it would include only coordinates and a zero value for all other plot parameters, but such plots would probably have a low value for both early detection and prediction of the occurrence of target species.

Plot shape: Sampling plots on roadsides, we noticed that most plot parameters (slope, light index, cover trees, shrubs, forbs, etc.) are very heterogeneous. Light index and tree cover could vary from 0 to 90 on the roadside and under trees near the road. Slope could vary from 0 to 40 degrees. Weeds were usually present along the road and not under dense tree canopy. On account of this, averaging environmental parameters probably masked characteristics that are typical for the microhabitat occupied by weeds. Despite this, following the sampling protocol, we did not change the plot shape and averaged those characteristics (with a couple exceptions where the notes were made on datasheets). For future applications, however, we recommend considering sampling not circular but linear plots on narrow roadsides.

Poor reception of Garmin and Trimble unit: A few times, we could not find the exact location of random points using the Garmin and Trimble units because of their poor reception. This occurred, for example, at random point 17 (segment 5) on Redwood Creek Trail. We got reception when we were already near random point 16 on the next segment, located about 500 m from point 17. We sampled random point 16, came back one segment, and spent at least 20 minutes looking for random point 17 because we lost reception again. Finally, we chose a random point based on the map.

Accuracy of projections of trails: Quite often, especially on very winding trails, the Garmin and Trimble units showed our position as off the trail when we were on the trail. In such cases, random points were actually not within 20 m from the trail but up to couple hundred meters. In such situations, we first tried to find the actual location of random points but later started sampling plots located near the point on the trail, which was closest to the random point (on the imaginary perpendicular line between random point and the trail).

Defining distance: In forests with dense canopy, when the Trimble unit did not have reception, we looked around for a place with more open canopy and better reception.

In this situation, the surveyor on the plot used the laser to measure the distance to the surveyor with the Trimble unit. However, in many cases like this, dense shrubs and tree branches blocked direct vision and the laser could not be used. Therefore, we completed a less accurate visual estimate.

Numbering segment boundaries: There were two different ways of numbering a segment's boundaries on the trails: (1) T0, T1, T2, T3, T4, T5, T6; and (2) T1, T2, T3, T4, T5, T6, T0. It was a bit confusing because in the first case, the third segment is located between points T2 and T3, while in the second case it is between points T3 and T4. It does not matter which system is chosen, but we recommend using the uniform system of numbers for segment boundaries.

Numbering random points: Random point numbers should strictly follow an ascending order. They almost always did, with a couple exceptions when the random point on the next segment had a smaller number. In those cases, it took us additional time to figure out which point we should look for. The problem occurred because not all numbers appear on the Garmin's screen. For example, numbers of some points that overlap with segment boundaries do not appear. The problem can be solved when a closer zoom is applied, but it is still helpful when the random points are in ascending order. Another complication arose a few times on winding trails when random points were very close to each other.

Suggestions about Datasheet Structure

Front and back sides of datasheets: The datasheets we used have forms for two plots on one sheet of paper. Filling in the form's back side, we needed to turn the paper around and place it on the clipboard again. After that, the back side of the left form appears on the right side of the sheet and vise versa. Even though we always kept this in mind in the field, with many other things to think about, approximately one out of four times we filled in the wrong side of the datasheet. It would be easier if the form for one plot is on one paper sheet and even better if all information is on one side of the sheet.

The table on the back side: A table with the list of all invasive species we were surveying was on the back side of every datasheet. We did not use it very often. It would be enough to have this list on a separate sheet on the clipboard under the datasheets. It also would save space for additional comments or drawings for the surveyor to use.

Waterproof paper: We recommend printing datasheets on both regular and waterproof paper. Only four days of the five weeks of field work required using waterproof paper.

Hydrological types: Sometimes the three categories that describe the hydrology of the plot (Flooded, Saturated, and Upland) could not precisely characterize the plot hydrology. For example, river terraces were neither flooded nor saturated at the time of sampling, but they were not uplands either because they flood on a regular basis.

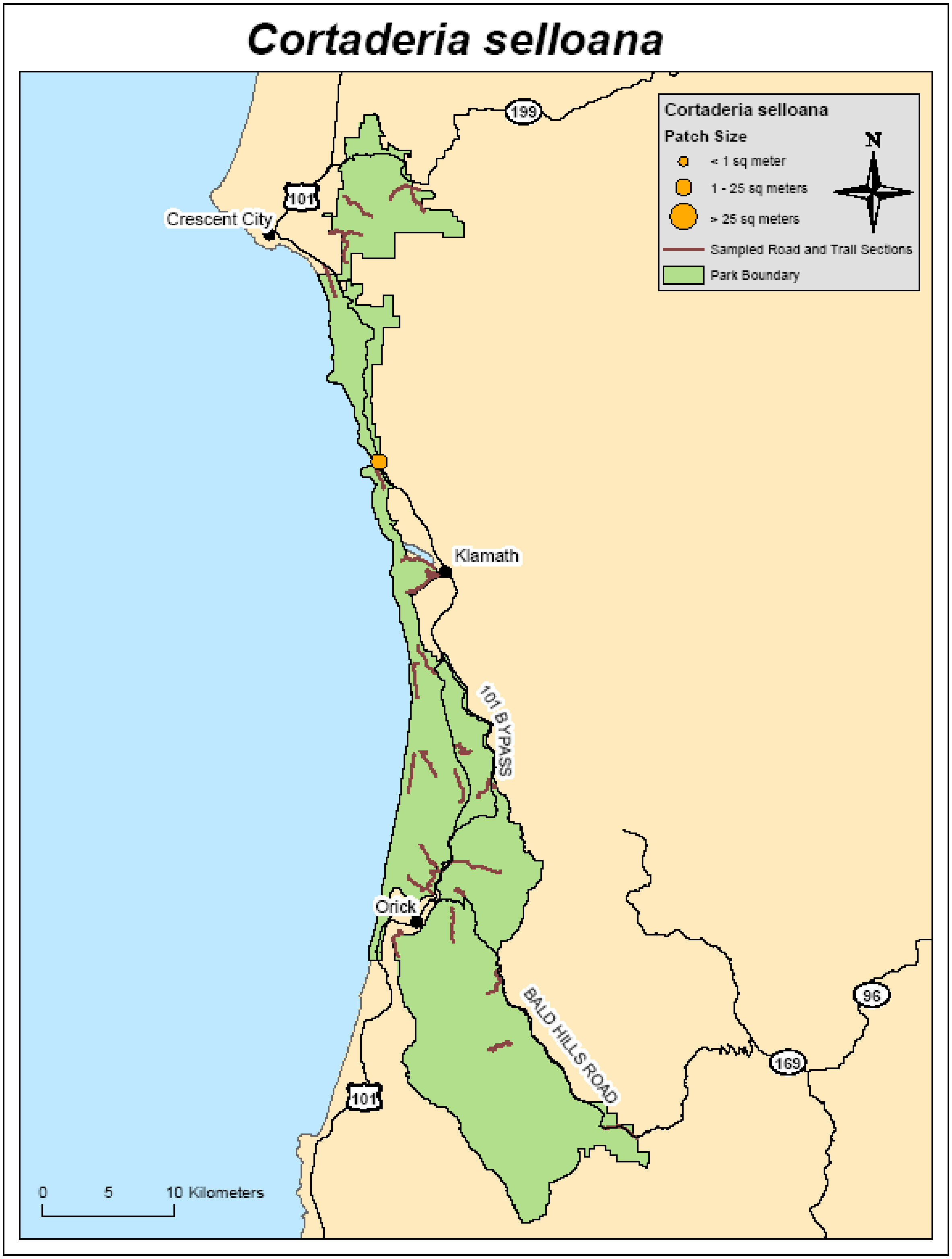
Aspect and Slope: These two categories are mentioned twice on the front side of the datasheet; one should be removed.

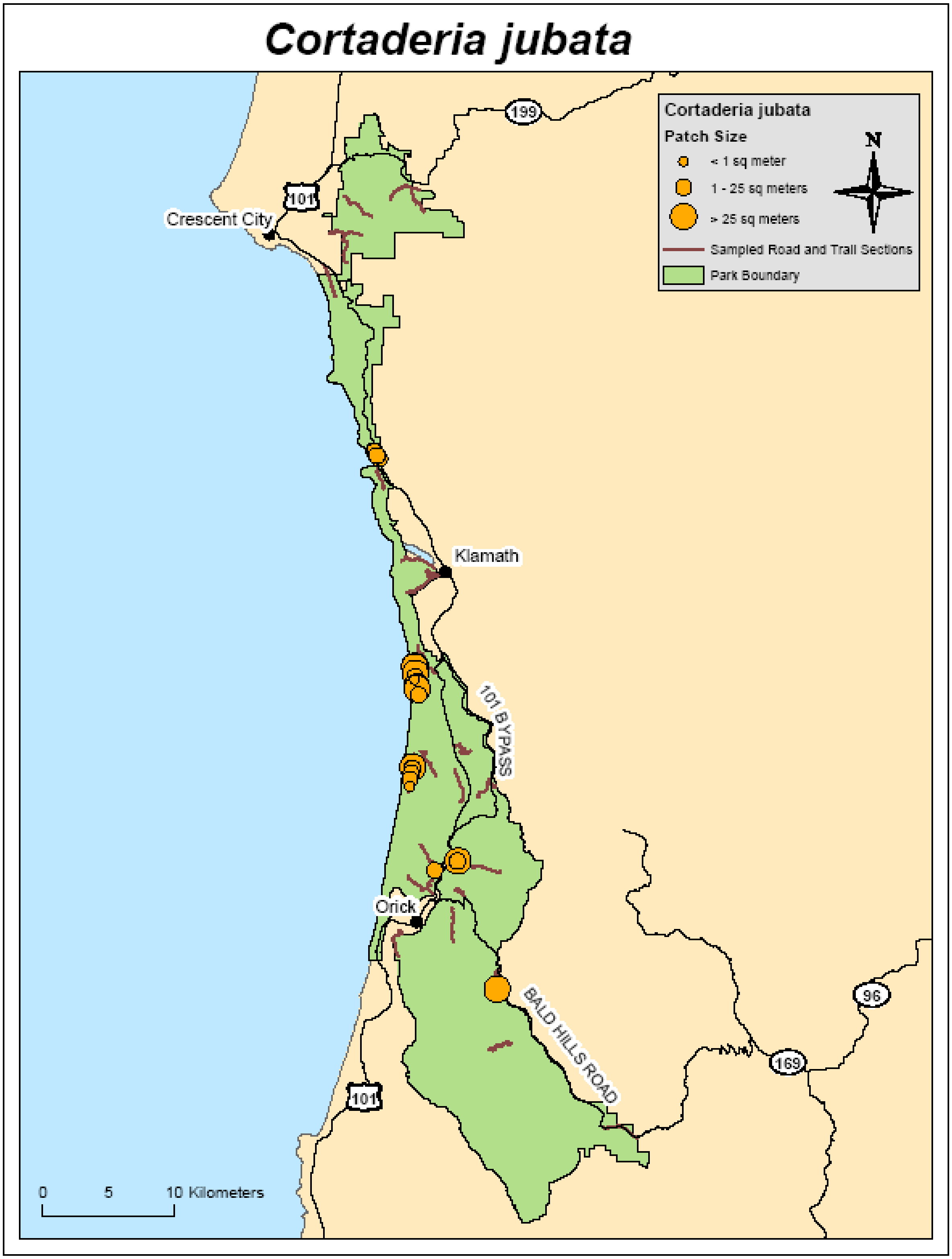
Literature Cited

Odion, D. C., D. A. Sarr, S. R. Mohren, and R. C. Klinger. In review. Invasive plants adaptive sampling early detection draft protocol: *Klamath Network*. Natural Resource Technical Report NPS/KLMN/NRTR—2008/001. National Park Service, Ft. Collins, CO.

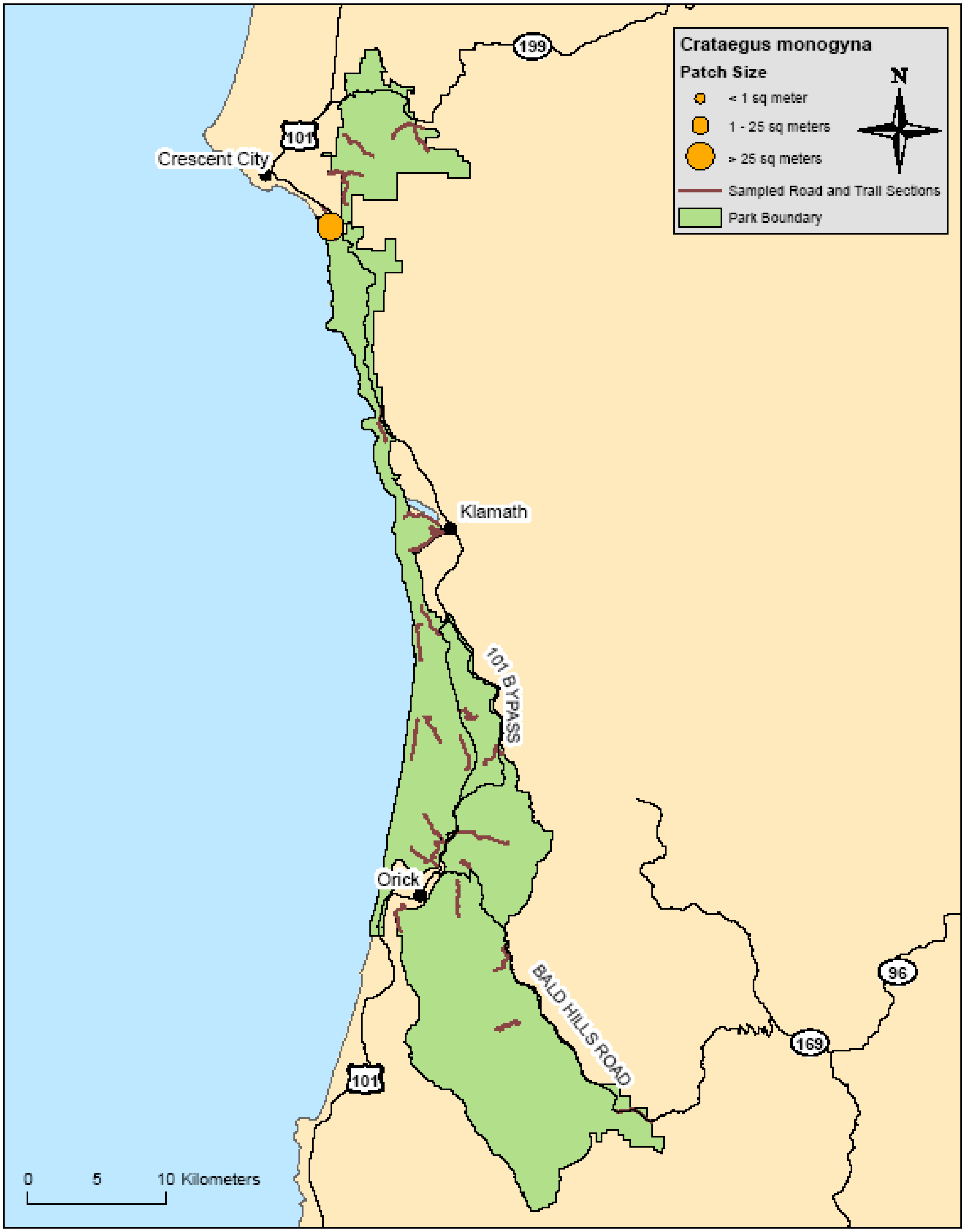
Randall, J. M., N. Benton, and L. E. Morse. 2001. Categorizing invasive weeds: The challenge of rating the weeds already in California. Pages 203-216 *in* R. H. Groves, F. D. Panetta, and J. G. Virtue, editors. Weed risk assessment. CSIRO Publishing, Collingwood, Australia.

Appendix A. Maps of Invasive Species Occurrences Detected during the Pilot Study at Redwood.

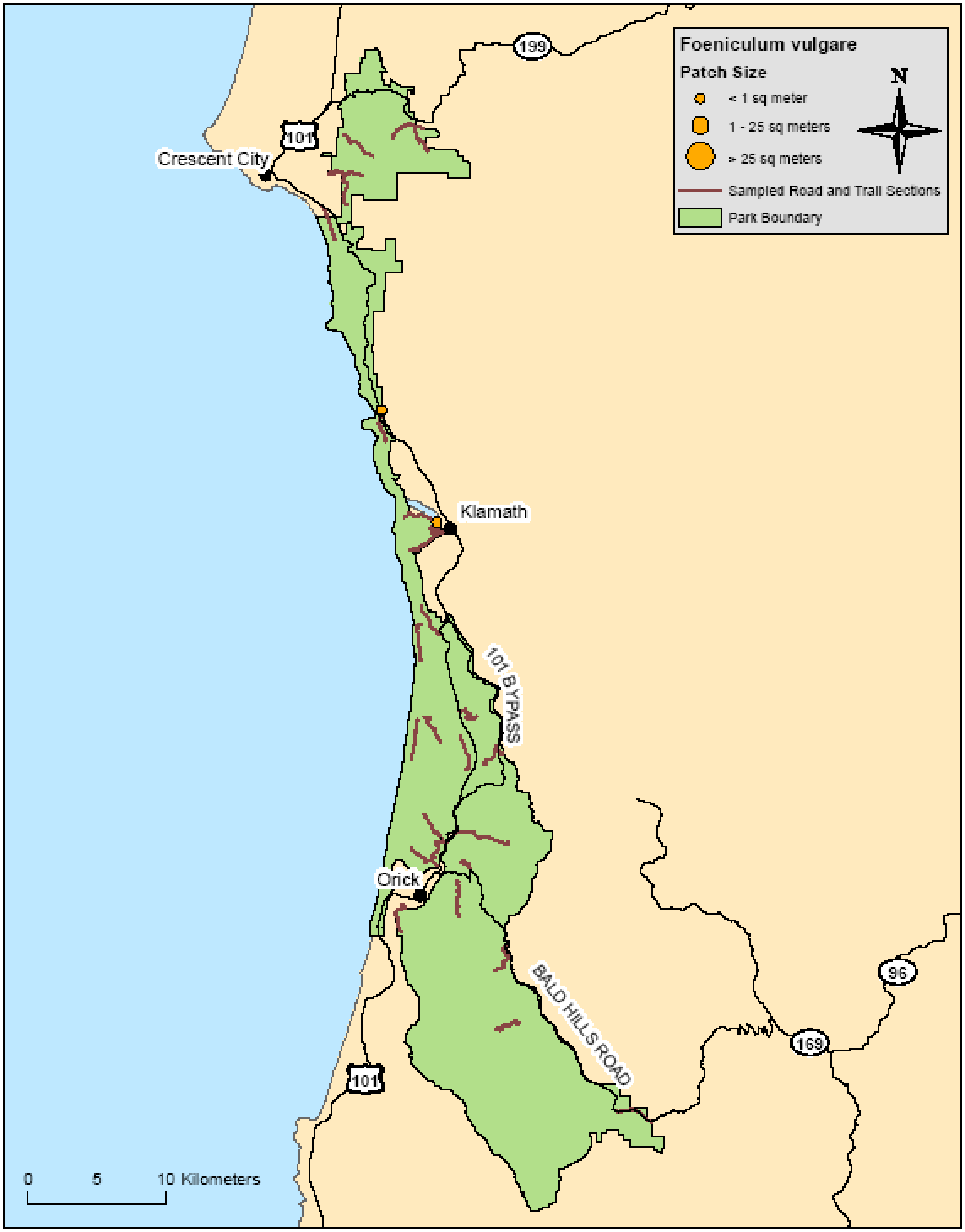


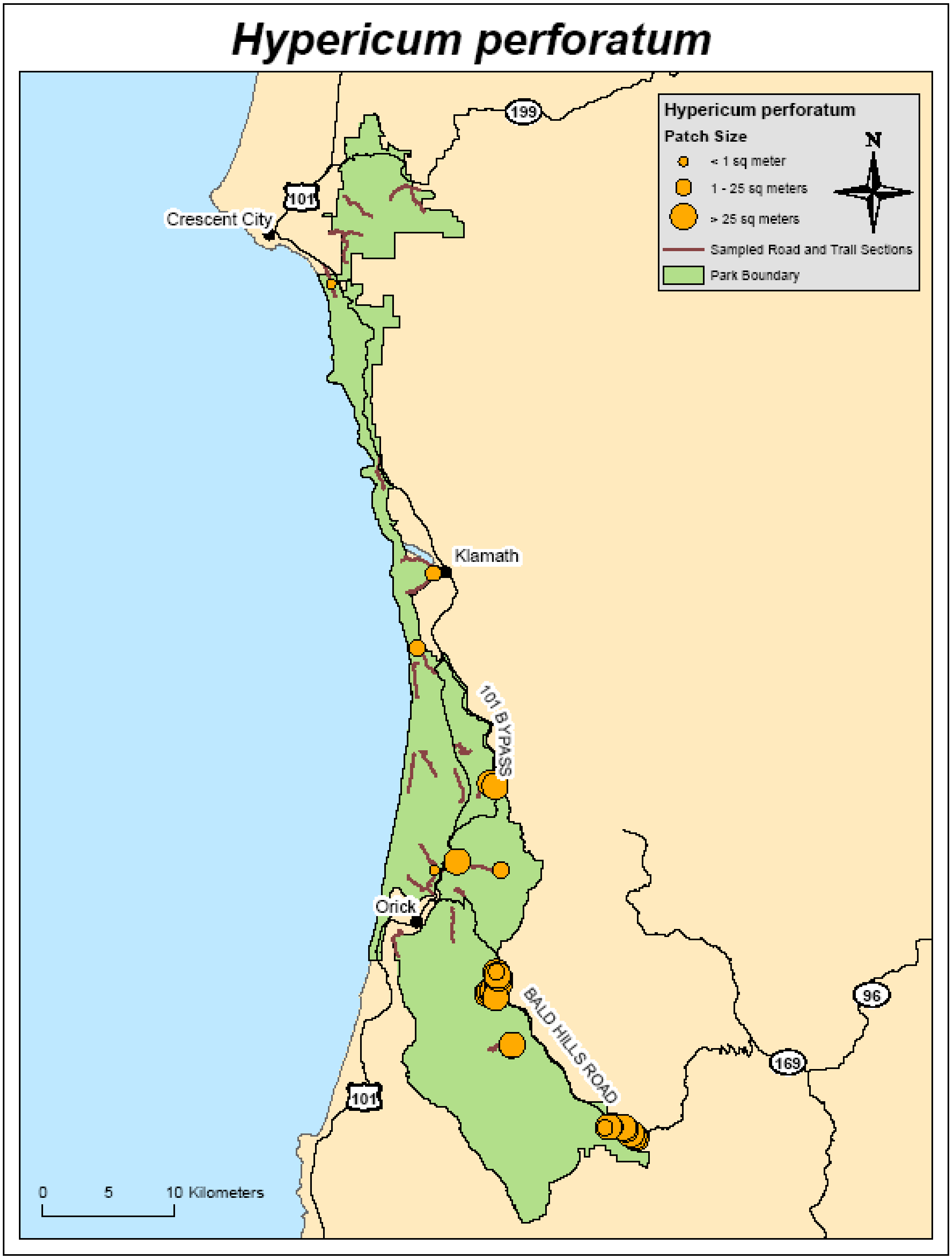

Cortaderia jubata
Cortaderia jubata
Patch Size
< 1 sq meter
1 - 25 sq meters
> 25 sq meters
Sampled Road and Trail Sections
Park Boundary
N
199
101
Crescent City
Klamath
101 BYPASS
Orick
BALD HILLS ROAD
96
169
101
0
5
10 Kilometers

Crataegus monogyna

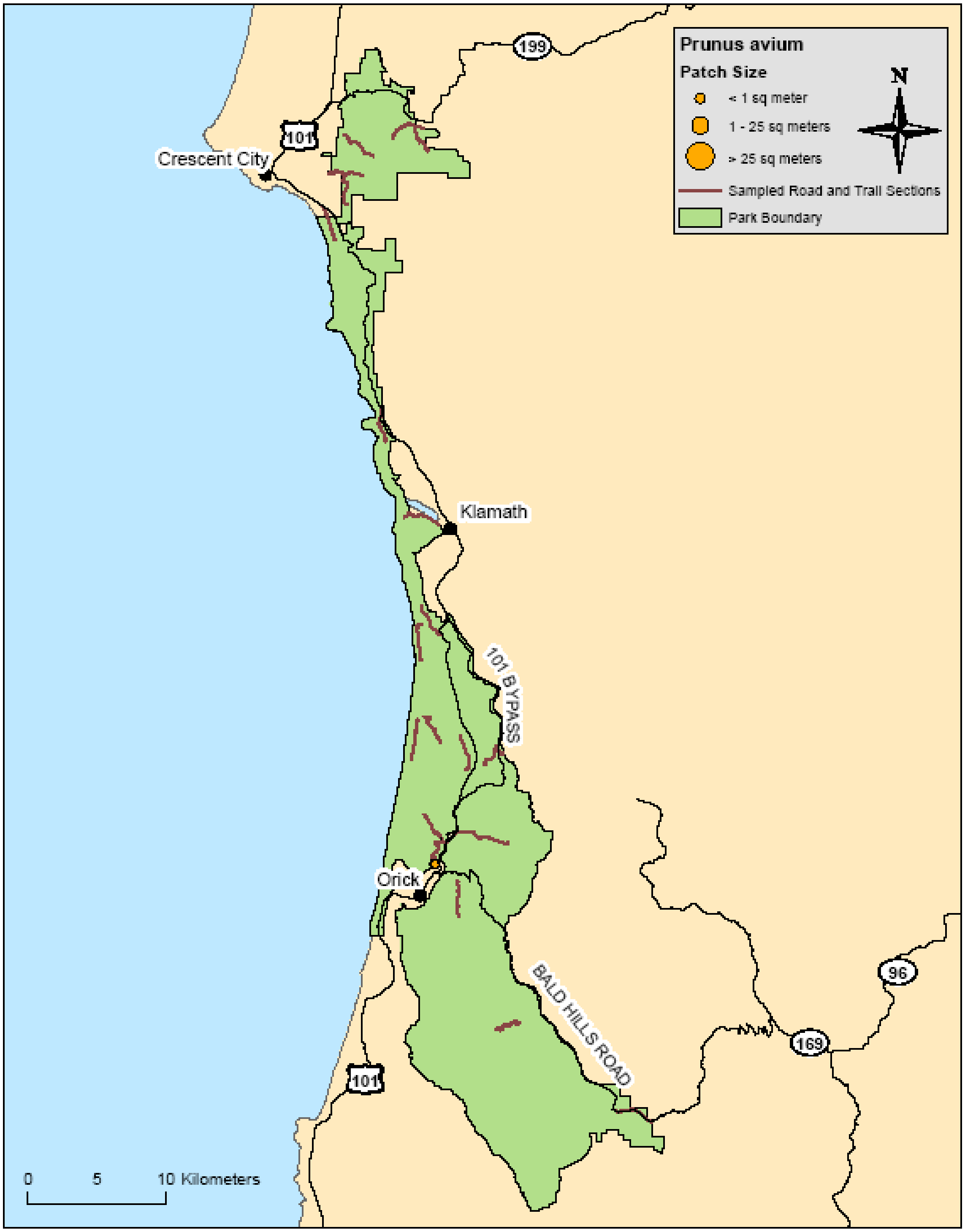


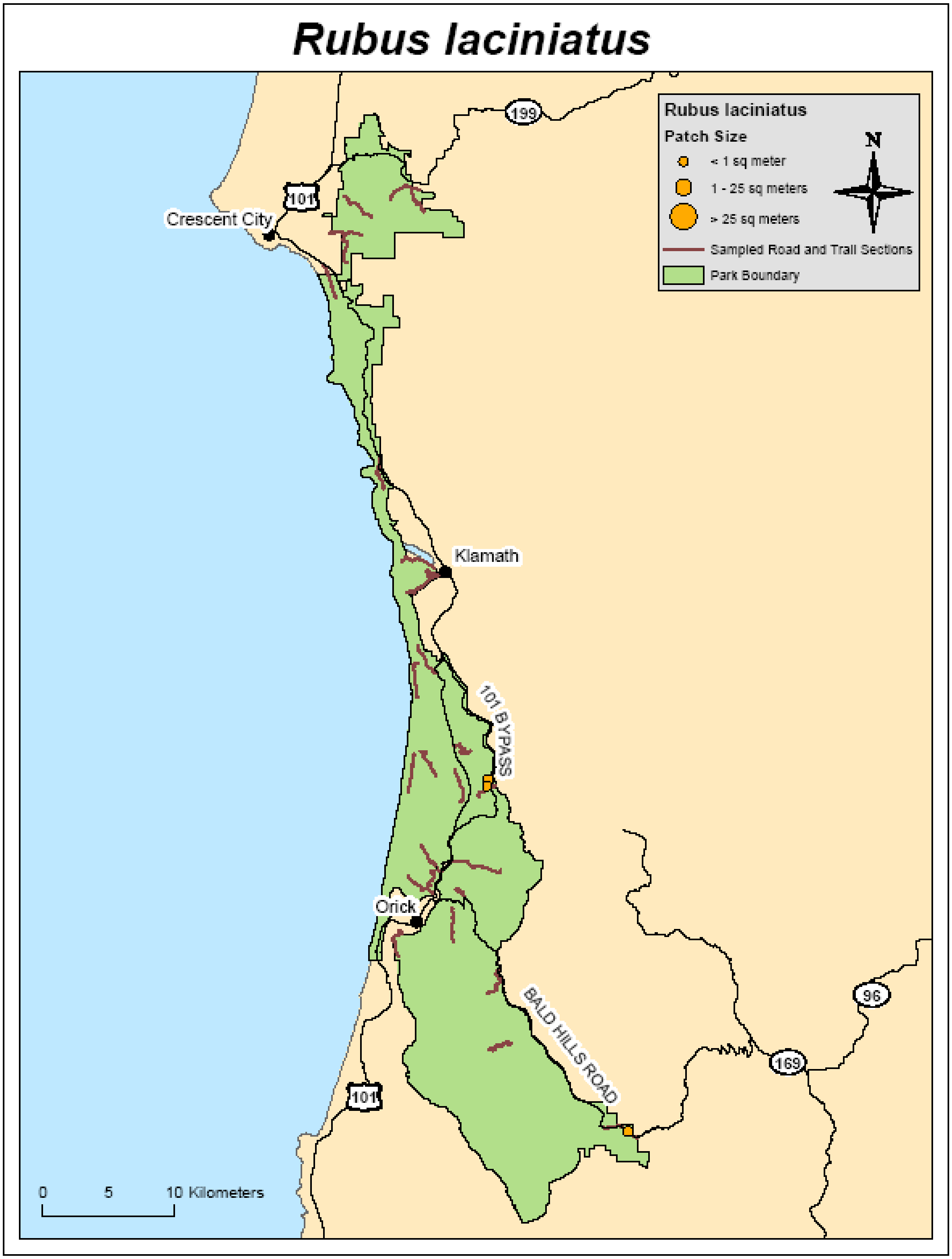
Foeniculum vulgare




Hypericum perforatum
Hypericum perforatum
Patch Size
< 1 sq meter
1 - 25 sq meters
> 25 sq meters
Sampled Road and Trail Sections
Park Boundary
N
199
101
Crescent City
Klamath
101 BYPASS
Orick
BALD HILLS ROAD
96
169
101
0
5
10 Kilometers

Prunus avium




Rubus laciniatus
Rubus laciniatus
Patch Size
< 1 sq meter
1 - 25 sq meters
> 25 sq meters
Sampled Road and Trail Sections
Park Boundary
N
199
101
Crescent City
Klamath
101 BYPASS
Orick
BALD HILLS ROAD
96
169
101
0
5
10 Kilometers

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